

Solar Photovoltaics—Stand-Alone Applications

James N. Deyo

*National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio*

The Lewis Research Center has been involved in space photovoltaic research and development activities since about 1963. About 1970, we began to look at the feasibility of using photovoltaics for terrestrial applications and worked with a number of small experiments in the early 1970's. Then in 1975 we entered into the National Photovoltaics program described earlier by Dr. Ferber. The program started with the National Science Foundation, was transferred to the Energy Research and Development Administration and then later to the Department of Energy (DOE). About 1977 we entered into an agreement with the Agency for International Development (AID) to carry out a project in Upper Volta, West Africa. This project and other activities of the AID program are described in this paper in addition to our work for DOE.

For DOE, Lewis' role is the Stand-Alone Applications project. "Stand alone" means applications that are not associated with a utility grid or with central power. They are applications in which the normal source of power may be a diesel generator, batteries, or other types of power not connected to a utility grid. Our purpose is to accelerate penetration of photovoltaic systems in both near-term and intermediate markets for these applications and to work especially in the international sector. In that

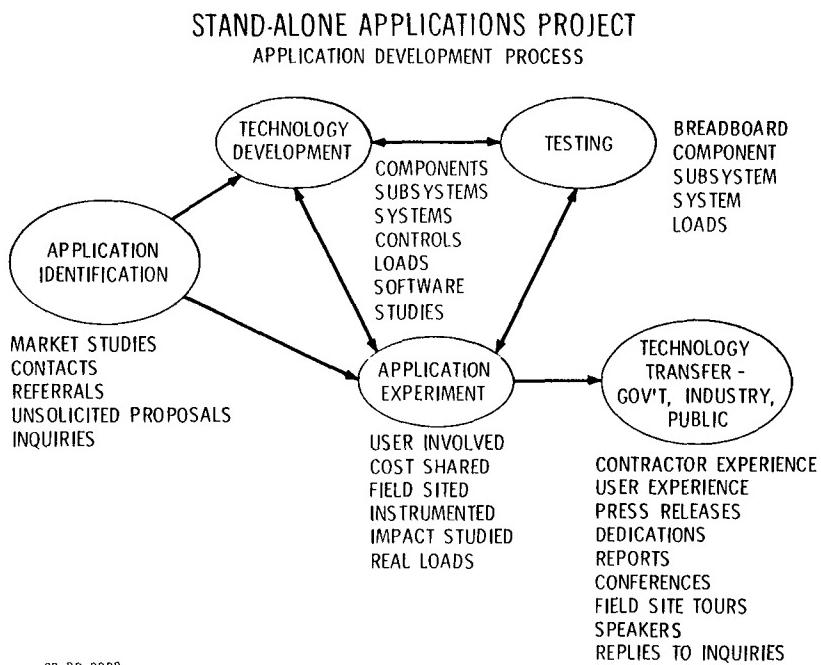


Figure 1

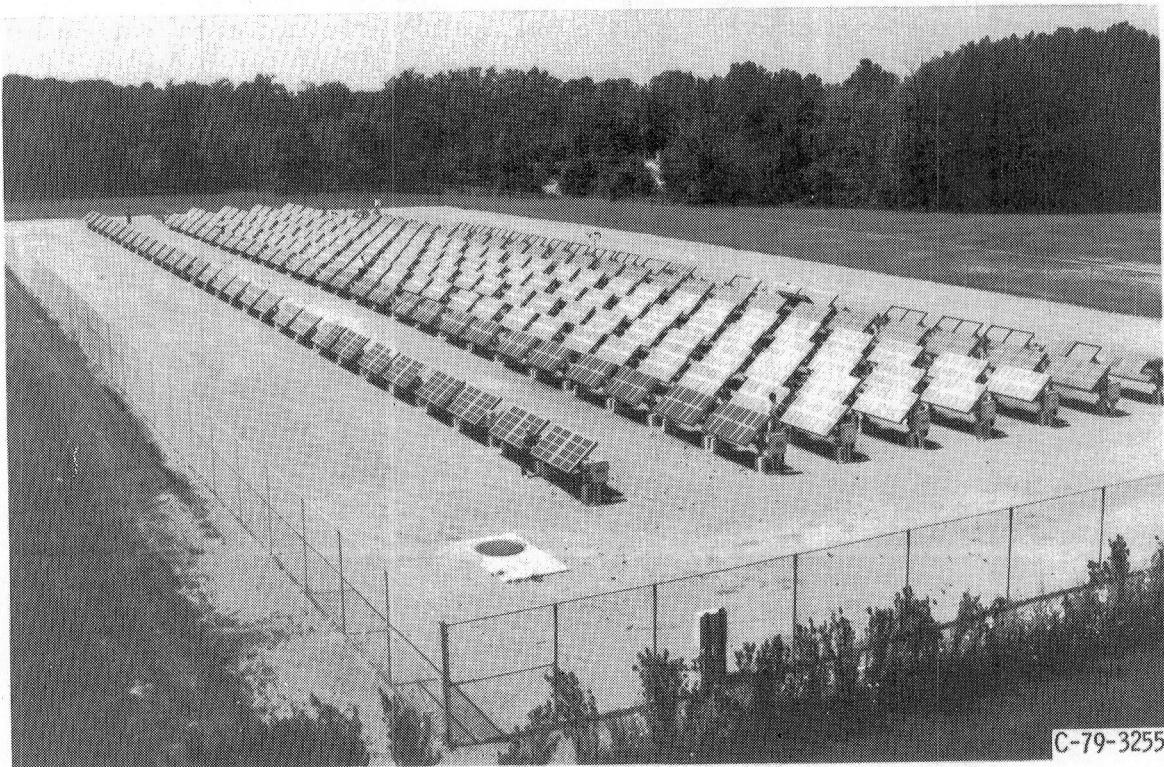
sector we are working primarily with developing countries. These countries represent the first major market for photovoltaic applications at this time.

Lewis' activities involve both development and implementation of applications as well as development of the technology for systems, subsystems, and components as needed. Figure 1 describes the process that is involved. The process begins when an application is identified by any of the methods shown. We then determine what technology developments are needed to carry out that application. We also begin to define an experiment that can be developed to demonstrate the application. In our experiments we always involve a user. That user participates in the cost and provides a site for the experiment that is part of the user's operation. We instrument the experiment to gain as much information as possible and of course study the effects of the application. We also conduct testing at all levels here at the Center to ensure that, when systems begin operation in the field, they will work as well as we can reasonably expect. And of course the purpose of all this activity is not to keep the information here, but to transfer it to industry, to the public, to other Government agencies, and to people who will make use of it and apply photovoltaics in other applications. This conference is one example of how we transfer this information.

Figure 2 shows the Lewis photovoltaic system test facility. Presently there are about 30 kilowatts of solar cells installed in this facility. In it we can breadboard systems and determine their characteristics, their interactions, and how they are going to operate before they go to the field.

Lewis has worked with quite a variety of applications over the last 5 years. Table I lists the smaller applications Lewis has fielded in which the power was used for a single purpose. The variety of categories shown includes instruments, communications, refrigeration, and highway. In all cases we have worked with a user such as the Coast Guard, the National Park Service, the Department of

LEWIS PHOTOVOLTAIC SYSTEM TEST FACILITY



C-79-3255

Figure 2

TABLE I.—LEWIS SINGLE PHOTOVOLTAIC APPLICATIONS

Application category	Use	User	Date operational	Location	Power level, W _p
Instrument	Weather data	USCG	Dec. 1972	Cleveland, Ohio	30
Instrument	Weather data	NOAA	Aug. 1973	Mammoth Mountain, California	60
Communications	Radio repeater	USFS	July 1974	White Mountain, California	16
Communications	Educational television	Govt. of India	July 1976	(1) Ahmedabad, India (2) Sambalpur, India	55 55
Refrigeration	Food preservation	USNPS	June 1976	Isle Royale, Michigan	220
Refrigeration	Medical	Village residents	July 1976	Sil Nakya, Arizona (Papago Tribe)	330
Instrument	Weather data	NOAA	Apr.-Sept. 1977	(1) New Mexico (2) New York (3) Hawaii (4) Alaska (5) Maine (6) Florida	75-150
Highway	Dust storm warning sign	DOT-AZ	Apr. 1977	Casa Grande, Arizona	116
Instrument	Insect survey traps	USDA	May 1977	College Station, Texas	23, 163
Refrigeration	Water cooler	Interagency visitor center	Oct. 1977	Lone Pine, California	446
Instrument	Air pollution monitor	NJ-DEP	Nov. 1979	Liberty Park, New Jersey	360
Instrument	Seismic monitors	USGS	Jan. 1980	Kilauea Volcano, Hawaii	18, 18

Transportation, the State of Arizona, and the Department of Agriculture. Many of these experiments date back a number of years. Locations and power levels for these experiments are also shown.

Table II lists cluster applications Lewis has fielded. These are applications in which the power is used for a number of purposes rather than a single purpose. The largest system—3500 watts—is the village power system at Schuchuli, Arizona. This is the largest application that Lewis has dealt with up to now. The final application listed was developed in cooperation with AID. It is installed in Upper Volta, West Africa, and has a power level of 1800 watts.

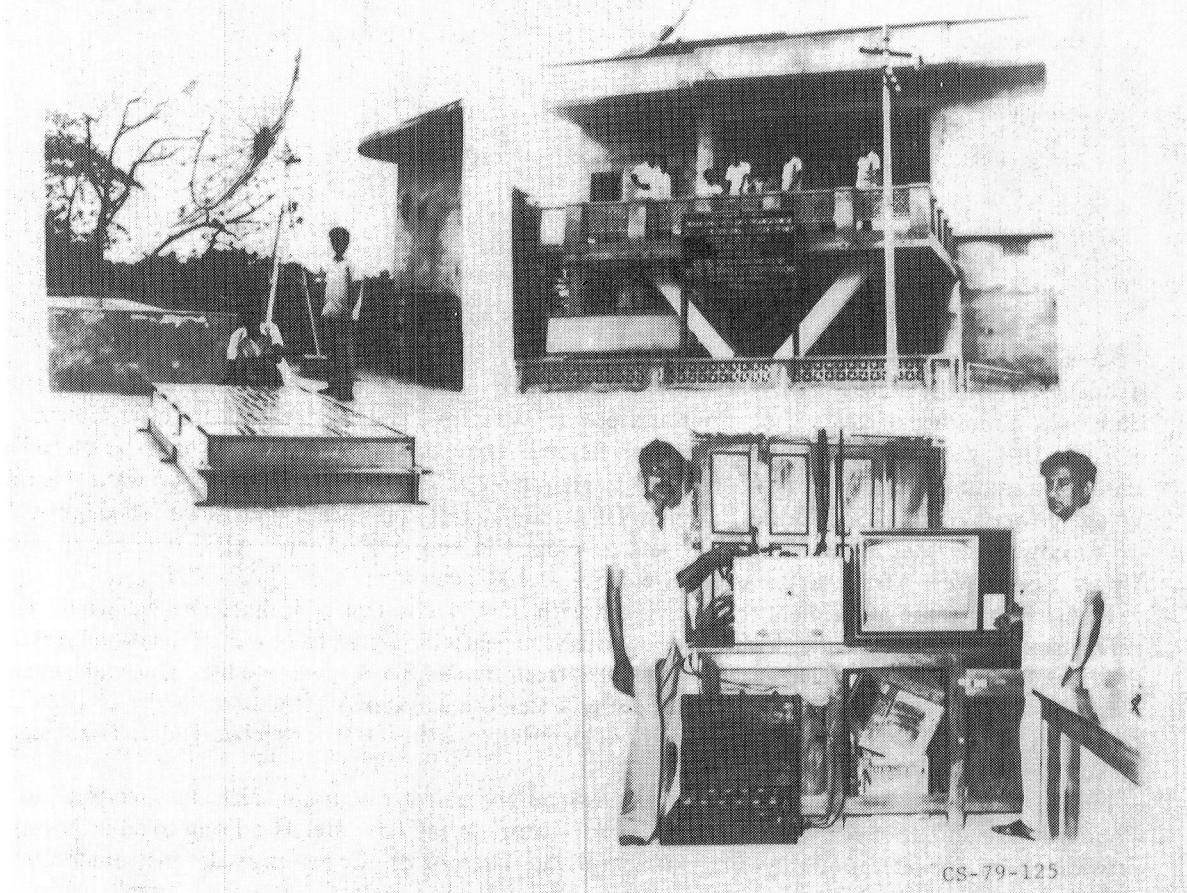
Figure 3 shows the experiment that Lewis did with the Government of India. Here we provided a small array of about 100 watts, with batteries housed beneath the array, to power a television receiver that was set up with an antenna to receive signals from the NASA ATS-6 satellite. This experiment was used to demonstrate the feasibility of using a satellite combined with solar energy to provide education to rural communities that are without electric power in countries such as India. The system performed quite satisfactorily.

Figure 4 illustrates an application involving a small portable array, about 220 watts, coupled to a standard 4.5-cubic-foot recreational vehicle refrigerator. In the base are six automobile batteries to provide power for operating the refrigerator at night. The box on the top provides instrumentation and some of the control functions. This system has operated satisfactorily at Isle Royale National Park during the summer seasons since 1976.

TABLE II.—LEWIS CLUSTER PHOTOVOLTAIC APPLICATIONS

Application category	Use	User	Date operational	Location	Power level, W_p
Fire lookout	Two-way radio, refrigerator, lighting, potable water	USFS	Oct. 1976	(1) Pilot Peak, California (2) Antelope Peak, California	294 294
Village power	Potable water, lighting, refrigerator, washing machine, sewing machine	Village residents	Dec. 1978	Schuchuli, Arizona (Papago Tribe)	3500
Village power	Potable water, grain milling	Village residents	Feb. 1979	Tangaye, Upper Volta	1800

PHOTOVOLTAIC-SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT
SAMBALPUR, INDIA



CS-79-125

Figure 3



Figure 4

Figure 5 depicts an application developed in cooperation with the Department of Transportation, State of Arizona. Arizona operates 40 of these dust storm warning signs along Interstate 10 between Phoenix and Tucson. We selected one of the signs and substituted the photovoltaic array and battery system for the existing power system to provide power for the sign. The power of the array is about 116 watts. The array provides power to rotate the sign, to operate the radio communication link that activates the sign, and to activate the lights mounted on the sign.

Another application category, shown in figure 6, involves remote weather stations operated by the National Weather Service. Here Lewis has provided a small array to operate the weather instruments and also to power the data communication link that transmits the data back to the National Weather Service Headquarters. This weather station is off the coast of Maine. We have installed similar systems at five other locations, including one each in Alaska, Florida, New York, Hawaii, and New Mexico.

With the Department of Agriculture, Lewis has provided some small arrays to power insect survey traps. These are shown in figure 7. The advantage of photovoltaics in this application is that it allows much more flexible siting of these insect survey traps. Normally researchers have to use a long extension cord to power these units from utility power. That becomes a little awkward when the

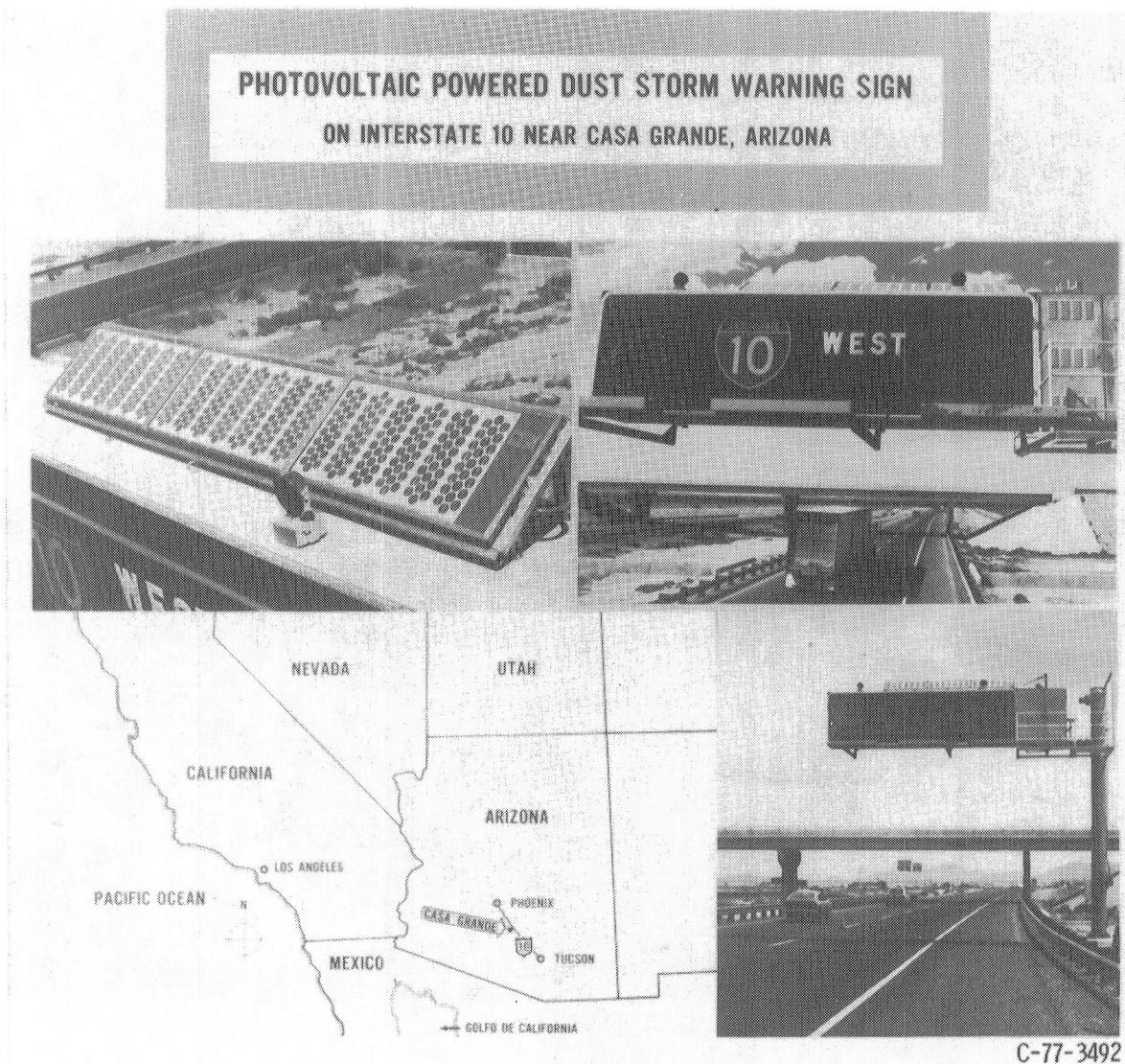


Figure 5

farmer plows the cord up with his tractor, and it also limits the locations where the traps can be placed. Photovoltaics has provided a flexibility that the agricultural people did not have before.

One of the cluster applications is shown in figure 8. This experiment was carried out with the National Forest Service. The application required a 300-watt array to provide power for operating the lookout. These lookouts are manned 24 hours a day throughout the fire season, which lasts about 6 months of the year in this area. The power is used to operate, for the tower operator, a refrigerator, a small pump that pumps water to the sink in the cab from a holding tank in the base of the tower, two-way radio, and lights in the tower. These have been very satisfactory applications. They have been operating since 1977.

With the State of New Jersey, Department of Environmental Protection, Lewis has provided a 360-watt array to power a standard high-volume air sampler, as shown in figure 9. This air sampler is located at Liberty State Park in New Jersey, directly across from the Statue of Liberty. It is a new park that the State of New Jersey is developing. The design for this system provides both a display for the public and an operational system for powering the air sampler. With this setting we have the

PHOTOVOLTAIC-POWERED WEATHER STATION OFF COAST OF MAINE



Figure 6

opportunity to inform the public about photovoltaics, to show an example of what can be done, and to provide a source of power for a practical application.

The village of Schuchuli, Arizona, is shown in figure 10. This is a village of 95 people on the Papago Indian Reservation. It is 17 miles beyond the end of the electric power line. Here Lewis has installed a 3.5-kilowatt array. Power from the array is carried to the small building in the right foreground of the figure. This building houses the controls and batteries for the system. From that point part of the power is fed to an electric motor that drives the community water pump. The water is pumped into a large storage tank for village use. The balance of the power produced by the photovoltaic system is then distributed by pole line around the village and used for lighting, refrigeration, and washing and sewing machines, as shown in figure 11. All the appliances are direct-current (dc) powered, and the power is distributed as dc at 120 volts.

For AID, Lewis' activities have involved management of the Upper Volta project, mentioned earlier as an initial effort with AID. Since then the Center has been asked to manage the AID Photovoltaic Development and Support project. The purpose of this project is to demonstrate the suitability of photovoltaic technology to provide energy for development applications in countries that AID works with. The approach is to design, develop, and deploy these systems in a number of real settings. Some of the application categories involved are health delivery, communications, education, and water pumping.

Figure 12 shows the Upper Volta project. Upper Volta, located in the western part of Africa, is at the southern edge of the Sahara Desert. In the village of Tangaye, a photovoltaic system has been installed to provide power for pumping water and grinding grain. The photovoltaic array produces 1.8 kilowatts peak of power and is coupled to a lead-acid storage battery through a control panel that automatically controls and monitors the system. In addition to operating the water pump, located on top of the well, power is carried into the building to drive a grain mill. A light in that building is also powered by the array. This system has been in operation since March 1979 and is operating quite satisfactorily.

PHOTOVOLTAIC POWERED INSECT SURVEY TRAPS
NEAR COLLEGE STATION AND NAVASOTA, TEXAS

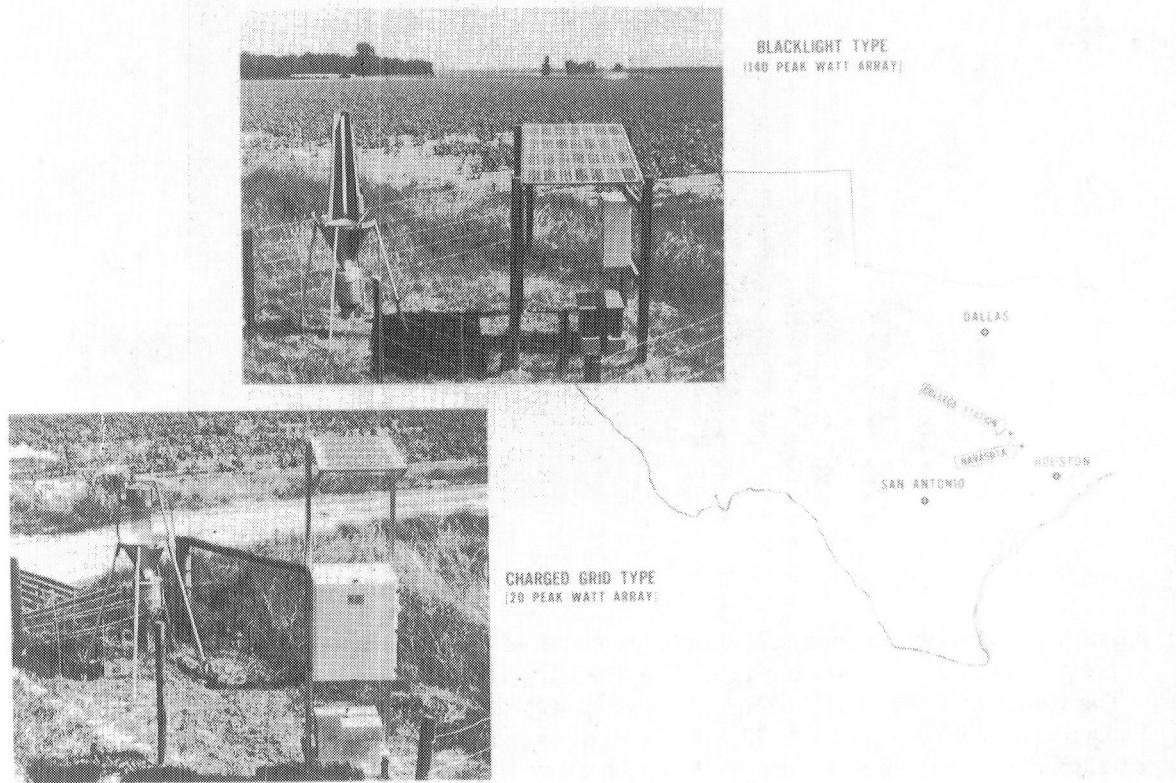


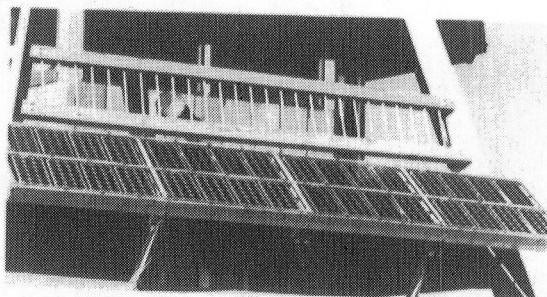
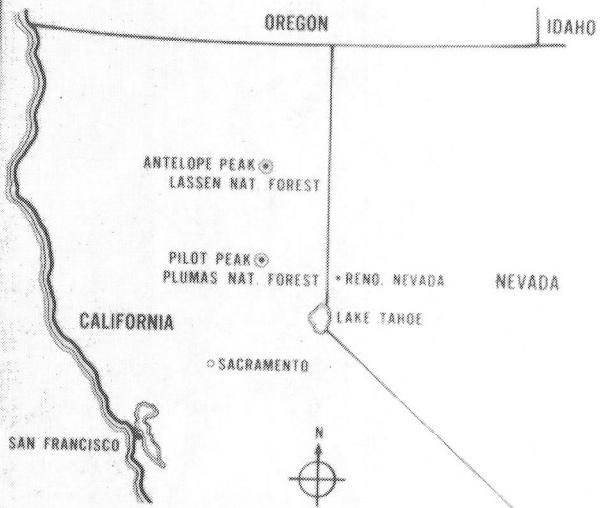
Figure 7

In conclusion, the development of photovoltaics has been proceeding for several years without much awareness by the public. But gradually more and more cost-effective applications are surfacing as the cost of photovoltaics comes down and the costs of other sources of energy go up. As these applications further develop and are noted in the news, the public will begin to realize the potential of photovoltaics. There are a lot of business opportunities developing—not just in making modules, but also in assembling systems. That area has not yet been penetrated very much by industry. The job of producing photovoltaic systems is a relatively straightforward engineering job. It involves providing batteries for storage (if the application requires it) electronic or electrical controls, wiring, connectors, enclosures, and the mechanical structure to support the array. These are tasks that many companies can readily adopt.

One example showing that some commercial interests are watching this technology carefully and are beginning to become involved with it is the case of Sears Roebuck. In Sears 1980 farm catalog you can buy a photovoltaic-powered electric fence charger. When a company such as Sears adopts a new technology, you know it must have some commercial potential to it.

PHOTOVOLTAIC POWERED FOREST LOOKOUTS

LASSEN AND PLUMAS NATIONAL FORESTS, CALIFORNIA



C-76-4766

Figure 8

PHOTOVOLTAIC-POWERED AIR SAMPLER
LIBERTY PARK, NEW JERSEY



Figure 9

3.5-KILOWATT PHOTOVOLTAIC VILLAGE POWER SYSTEM
SCHUCHULI, ARIZONA



Figure 10

PHOTOVOLTAIC-POWERED APPLIANCES AT SCHUCHULI, ARIZONA

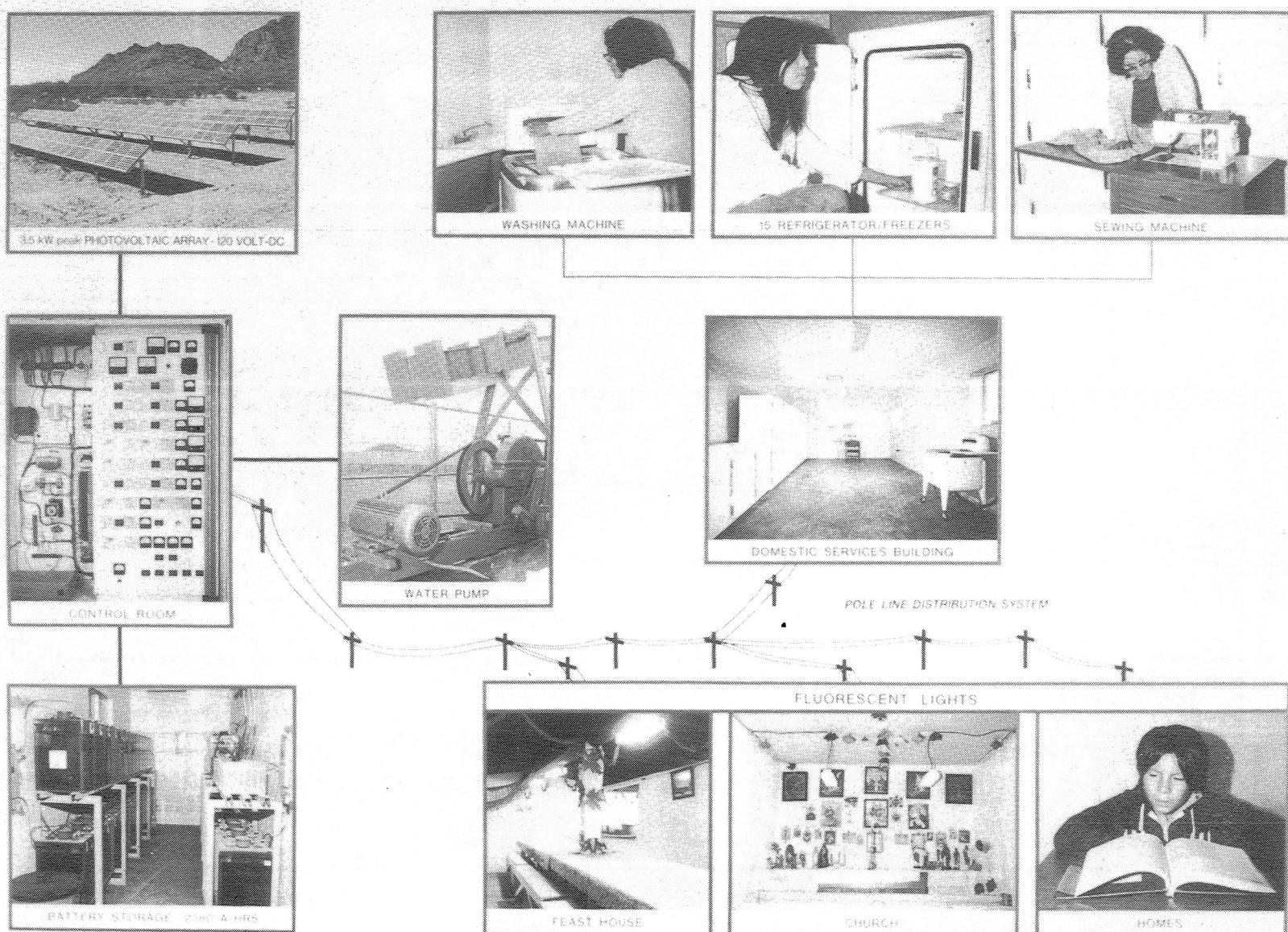


Figure 11

TANGAYE VILLAGE PHOTOVOLTAIC SYSTEM

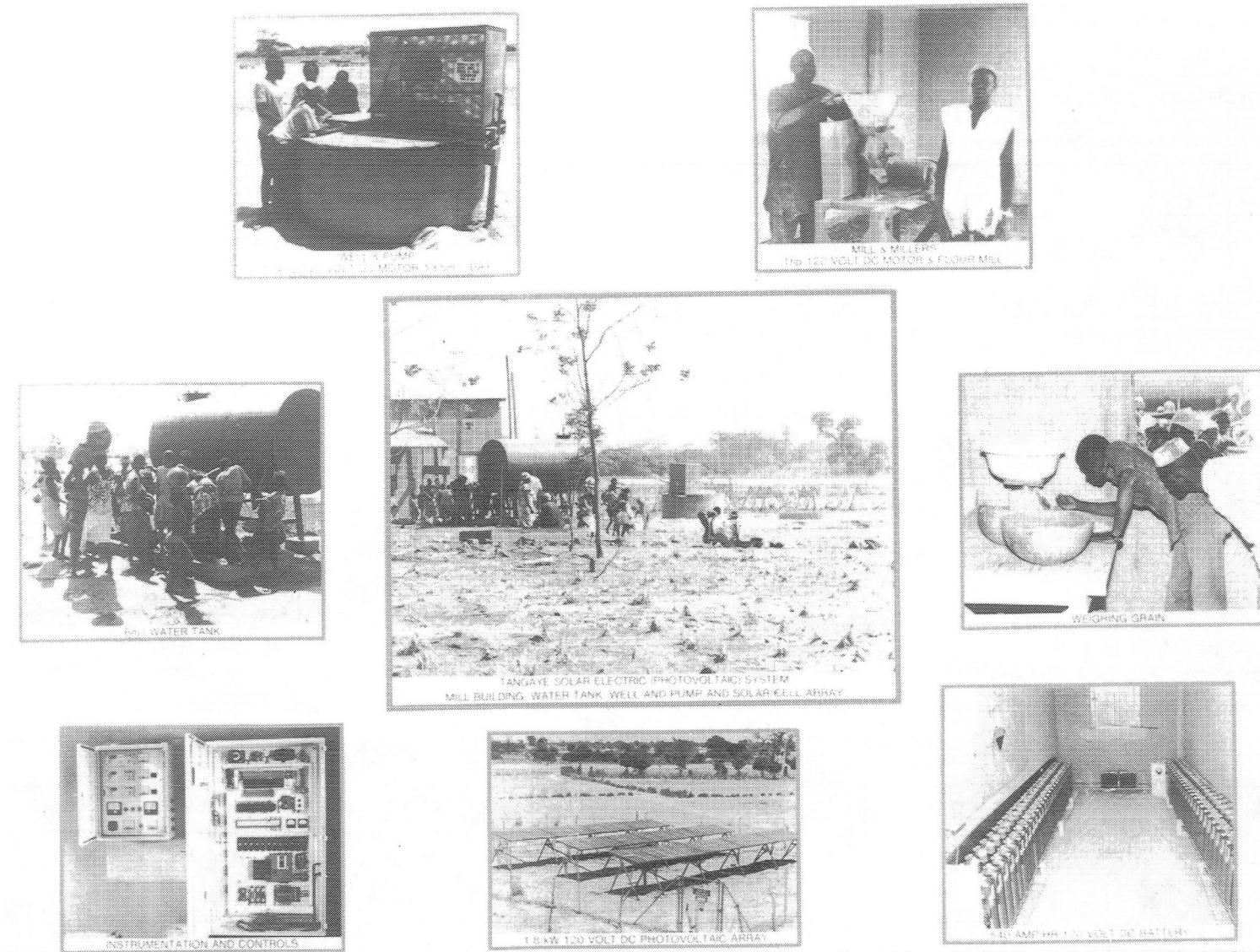


Figure 12

U-79-Z3/1

Introduction to Materials Processing in Space

John S. Foster, Jr.*

TRW, Inc.

Cleveland, Ohio

This conference has been discussing ground-based energy and transportation both on the ground and in the atmosphere, areas in which we as a society have become dependent and areas which are also now highly industrialized. In the next paper, we are going to space. And we should recognize that, although we have been in space technology only a couple decades, we have already become quite dependent on it for information and knowledge. The information and knowledge come to us by means of communication satellites, weather satellites, reconnaissance satellites, and soon by navigation satellites. In addition, space technology is becoming industrialized.

Satellites have become indispensable servants for us in just a short time, and NASA is now experimenting with the possibility of manufacturing items in space and bringing back material that is unique because it has been processed in that unique environment. This idea of making special materials in the near zero-gravity environment of space has been a dream for more than a decade, and preliminary experiments were begun about 10 years ago. These were what you might call weightlessness experiments and were tried first on Apollo, then on Skylab, then on Apollo-Soyuz, and more recently on small sounding rockets.

The preliminary results of the experiments are promising; they give indications that what people thought might happen seems to be happening. In order to undertake this kind of early research program on materials processing in space, NASA has, it seems to me, used a sensible approach, and done things in a balanced way. As a sometimes bureaucrat, I find that rather uncommon. In particular, it seems to me that the NASA approach in providing an opportunity for industry and universities and NASA in-house laboratories to work closely together from the outset on a common set of national pursuits is rather unique. NASA is also constructively using the peer review as a mechanism for assuring a sensible balance at the various phases of the program. I find the entire approach to be well structured and productive.

TRW, my organization, became committed in the 60's to an effort of pursuing the technology of materials processing in space. We would like to become an industrial user of space, and to do so we want to participate in the initial experimental stage. For the last 2 1/2 years we have been looking at the opportunities and have been functioning as a marriage broker between the NASA organization and a number of industrial organizations that have possible interests in using space for materials processing. TRW is also involved with TDRSS, the Tracking and Data Relay Satellite System for operation with Space Lab and the Shuttle, which will play an important role in future experiments.

*Vice President, Science and Technology, TRW, Inc.